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SUBJECT: Review of Space Station Technology Program Plan - Case 610

DATE: February 4, 1970

FROM: G. M. Anderson, et al

MEMORANDUM FOR FILE

The Space Station Technology Program Plan has been reviewed to identify AAP technological support. To adequately cover the variety of subjects, reviewers were drawn from disciplinary areas within Bellcomm as well as from the AAP Systems Engineering (MLS).

As a guide, each reviewer was instructed to conduct the review with two primary objectives in mind:

1. to identify the support AAP is currently planning for the Space Station/Space Base (SSB), and

2. to identify potential support which AAP might provide for the SSB Program.

In addition, each reviewer was encouraged to offer any suggestions they may have for strengthening the Plan itself.

The attached responses catalog a wealth of real and potential AAP support for the SSB. Many problems are commonly shared by the AAP SWS cluster, which is a first space station, and the future more sophisticated SSB. Therefore, much of the basic technological experience gained in AAP is applicable to the SSB. An indication of this is manifested in the suggestions offered by some reviewers for strengthening the SSB Plan.

Finally, specific SSB related experiments and technological advances could be added to AAP. Some suggestions are enclosed. Scheduling constraints preclude any substantial additions to SWS-I, however, SWS-II may offer a better opportunity.

G. M. Anderson

1022-GMA-mef/cf

G. M. Anderson

Attachments

01. STRUCTURES - R. K. McFarland

Present AAP Support for the SSB

1. SWS-I currently has one experiment that can be said to support SSB in the structures area, D021, which is the Expandable Airlock Technology Experiment. A listing of candidate experiments for SWS-II includes a topic "Large Expandable Space Structure", which refers to large solar arrays, parabolic dishes, and dipoles. Apart from these two items, there are no specific experiments on SWS-I or proposed for SWS-II which would support the SSB in the structures area.

2. Structural technology or engineering precursor developments planned for SWS-I in support of SSB are:

   A. Development of large deployable solar arrays. Small deployable solar arrays have been used in the past for manned spacecraft; however, SWS-I will be the first manned spacecraft using a solar array/battery electrical power system, and large deployable solar arrays.

   B. Module docking will occur on SWS-I between the CSM and the OWS, the latter being a large flexible vehicle. The techniques and structure involved have been taken directly from the Apollo Program; however, further refinement of the residual closing rates and a better understanding of the resulting docking loads will be helpful to the SSB.

   C. A deployable meteoroid bumper will be used on the SWS-I. The development of meteoroid bumper technology will be directly applicable to a large area orbital vehicle that has a long operational lifetime.

   No additional structural technology or engineering precursor developments have been identified for SWS-II.

Potential AAP Support for the SSB

1. Experiments that could be added to SWS-I to support SSB are:

   A. Docking and latching loads instrumentation. Quantitative information on the loads imparted to the OWS through the MDA would be of considerable value to the SSB design. In particular, loads that would occur in the ATM and solar arrays, and the resulting decay rate (i.e., damping) would be most valuable. In addition, the measurement of the OWS free-free zero "G" nodal response would provide a unique opportunity to verify present analytical techniques, and to better understand damping characteristics of large structural systems in a zero "G" environment. This experiment could consist of instrumentation only.

B. Zero "G" sloshing. The response of liquids in rigid containers, in a zero "G" environment is not expected to be a problem for SWS-I. However, if SWS-II or SSB required extreme spacecraft motion stability, the fluid motion effects could be troublescme. As data for this type can be obtained only in orbit, SWS-I would provide a unique opportunity to evaluate the loads due to zero "G" sloshing, and obtain damping information. The experiment could be done with existing tanks, thus necessitating instrumentation only. However, various shaped tanks would immensely improve the experimental results.

Experiments to be considered for SWS-II in support of SSB are:

A. Meteoroid Protection. The Space Station Technology Program Plan states that a specific proposal for a meteoroid protection experiment on the Dry Workshop is being prepared. This is a thick material experiment, and will reduce the uncertainty in the impact flux, and provide means of improving penetration theories.

2. Structural technology or engineering precursor development that could be added to SWS-I or II.

For SWS-II, the use of a small area lightweight unfurlable solar array in conjunction with the present deployable arrays would provide the technology for SSB solar array areas much larger than those on SWS-I and SWS-II. The unfurlable arrays (i.e., roll-up arrays) have multiple deployment capability and could reduce solar array weight by as much as a factor of five of those on SWS-I.

02. THERMAL SYSTEMS - J. E. Waldo

Present AAP Support for the SSB

1. Currently planned AAP experiments which support SSB:

   (none)

2. Current AAP technology and engineering precursor developments which support SSB:

   AAP thermal control systems are characteristically Apollo state-of-the-art and involve no new significant advances that would support SSB. However, considerable experience has been gained in analyzing and integrating the various large, diversified, and complicated thermal control systems. Thermal network model reduction is an important part of this effort as carried out at MSFC and Bellcomm. Although the hardware may be different, it is expected the SSB will involve much the same kind of integration and analytical techniques.

Potential AAP Support for the SSB

1. Additional AAP experiments that could support SSB:

   A. Presently, a number of temperatures are measured and monitored during AAP missions (46 measured temperatures in the OWS alone). This provides an excellent opportunity to evaluate basic modeling techniques which is probably the biggest contribution that AAP could make to thermal systems design. The best way to achieve this is to assign a formal experiment, e.g. cut off all OWS waste heat and measure transient temperature response for some specified period. Later, after comparison with analytical predictions, basic techniques can be evaluated to underline analytical shortcomings. Scale model tests could be performed and compared with flight and analytical data to better establish modeling and scaling techniques.

   B. A large heat pipe could be wrapped around the OWS, or the AM-MDA, to establish, in space, the feasibility of starting, stopping and controlling heat pipes.

   C. Heat screens such as louvers, shades, or even inflatable screens and cocoons could be tried as experiments or incorporated as part of the basic design.

0.4 ATTITUDE CONTROL PROPULSION SYSTEM - J. Kranton

In general, the technology in attitude control propulsion is at a high level of maturity. But the long lifetime that would be required of the propulsion system on the SSB has not been demonstrated. Consequently, if the SWS-II has a requirement for substantial impulse, say more than 200,000 lb-sec, development may be justified for a long lifetime hypergolic bipropellant system or a monopropellant hydrazine system. (On the Wet Workshop, development had begun on a long life hypergolic bipropellant system.)

0.5 ELECTRICAL POWER - B. W. Moss

Present AAP Technology Support for the SSB

The following listed technology items being developed as part of AAP relate directly to areas specified in the support plan and are referenced to the appropriate plan page numbers.

1. Power Distribution and Control (5-2)

Present AAP plans call for parallel operation of the AM and ATM EPS's each rated approximately 4 kw. The techniques involved in power distribution, load switching and circuit protection are directly applicable although the SS/B load levels will be considerably higher. Component developments now in progress (5-5) would be directly applicable if space qualified. Computer simulation programs have been developed (Martin-Denver and Bellcomm) which permit evaluation of load-sharing performance of paralleled systems with different performance characteristics. These can readily be extended to systems with more than two sources and more than the present number of distribution points.

2. Power Conditioning (5-7)

The CBRM developed for the ATM has the capability of delivering 200 to 250 watts of regulated output and contains a rechargeable NiCd battery, a charger, and a regulator. The Power Conditioning Group (PCG) developed for the AM can deliver 525 to 550 watts of regulated output. While these are small considering the requirement of 25 to 100 kw for SS/B, the technology is directly applicable and these subsystems could be used without modification.

Inverters have been developed for providing ac power and have been flown in the CSM and LM. They are small in capacity (about 150 va) but the technology exists for providing reasonable blocks of ac power. The variable-speed constant-frequency (VASCOF) system under study by NASC is applicable only to a system using a driven alternator with no speed control.

3. Auxiliary Power Units (5-10)

Both the Pratt and Whitney and the Allis-Chalmers Fuel Cell Powerplants have been qualified for space flight. Each can provide 2 kw continuously, the PW unit for 1500 hrs and the A-C unit for 2500 hrs.

4. Multi-Kilowatt Solar Array/Battery Power Generating Program (5-17)

The AM EPS utilizes a 1360 sq ft solar array rated 12 kw using eight 33 AH NiCd batteries for an EPS continuous power capability of approximately 4 kw. The ATM EPS utilizes an 1160 sq ft solar array rated 10.5 kw using eighteen CBRM's (20 AH each) for an EPS continuous power capability of approximately 3.8 kw. This technology, while relatively unsophisticated compared to the available state-of-the-art, is easily extended using the present design into a larger capacity system (upwards of 25 kw).

5. Thermal Control for Power Generation Systems (5-22)

The passive cooling used on the ATM CBRM's probably cannot be extended much beyond the present system capability because of the physical limitations on size of radiating surfaces.

The cold plates for use on the AM PCG's are directly applicable to SS/B usage although limitations on heat rejection rate capability may hinder their usefulness.

The cooling system on the SM for use with the FCP's can certainly be used unmodified wherever the FCP's are used.

Potential AAP Technology Support for the SSB

The following listed technology items are those that could reasonably be added to or used in place of those baselined for SWS-I or planned for SWS-II.

1. An integrated EPS using the desired techniques described in the Plan could be flown on SWS-I to prove feasibility and to evaluate system performance. The system configuration could be

   A. Solar Array - two 250 sq ft roll-up (Ryan, Fairchild-Hiller, or GE). Array output is 5000 w at 40 to 100 v.d.c.

   B. Battery - four 33 AH AM batteries or eight 20 AH ATM batteries.

   C. Charger - four AM chargers or eight ATM chargers.

D. Inverter - 2.5 Kva 3 phase, 35 to 45 v.d.c. input, 120/208 v.q.c. output, select operating frequency in the range of 400 Hz to 1600 Hz.

E. Rectifier/Regulator - provide two or more rectifier/regulator combinations using AM regulator package for providing 28 v.d.c. locally as required.

2. Use Pratt and Whitney or Allis-Chalmers FCP's for auxiliary power instead of batteries. Improvement in life and maintainability is necessary if FCP's are to be considered. Radioisotope Thermoelectric Generators (RTG) have been flown and are attractive but only in the low power regime.

3. Consider the use of an Isotope Brayton Cycle Power System on SWS-II if a sufficient quantity of fuel (Pu 238) can be available.

06. LIFE SUPPORT - J. J. Sakolosky

Present AAP Support for the SSB

1. Current AAP Experiments Supporting SSB

   A. M507 Gravity Substitute Workbench -
   M508 EVA/IVA Hardware Evaluation -
   M151 Time and Motion Study -

   These three experiments support SSB by providing data on an astronaut's ability to perform simple work functions in a zero-g environment, on alternate zero-g restraint systems, and on the comparative ease or difficulty encountered by the crew in performing routine, daily tasks in a zero-g environment. These data will be useful in the design of maintainable systems for the SSB.

   B. M487 Habitability/Crew Quarters -

   This experiment will provide data for the design of crew quarters compartments in future spacecraft.

2. Current AAP Technology Supporting SSB

   A. The four bed, regenerable molecular sieve used for adsorbing CO_2 in the AAP Cluster will provide direct support to future molecular sieve development for the SSB.

   B. The AAP waste management system utilizes vacuum drying as a means of preservation prior to storage of feces. The "dry john" waste management system being developed by LRC for the space station also employs vacuum drying; experience gained from the AAP program may prove useful.

   C. The AAP Cluster two gas atmospheric control subsystem utilizes a Beckman O_2 partial pressure sensor to control total atmospheric pressure to $5.0 \pm .3$ psia and O_2 partial pressure to 3.7 psia nominal. Both MSC and LRC are expected to significantly utilize AAP technology in the design of a two gas control system for the SSP (Space Station Prototype) and the ILSS (Integrated Life Support System).

D. The AAP Cluster Water Management System utilizes iodine as a bactericide to control micro-organism growth. Iodine is one of the chemical additives under consideration as a bactericide for the SSB.

E. The integrated atmospheric control/thermal control subsystem which controls atmospheric temperature, humidity, CO_2 level, odors, and atmospheric circulation in the AAP Cluster will provide data applicable to atmospheric control of the large cabin volumes associated with SSB.

Potential AAP Support for the SSB

1. Potential AAP Experiments Supporting SSB

A. A full body shower experiment which would include a closed loop water reclamation system requiring periodic maintenance could provide support for SSB in several areas of future development. Operational data obtained from use of a full body shower in a zero-g environment would provide a substantial data base from which to design an optimum whole body cleansing unit for the SSB. Data obtained from the required in-flight maintenance functions (the breaking of water lines and replacement of expendable filters in the water reclamation system are envisioned) would be of use in the design of maintainable life support systems for the SSB.

2. Potential AAP Technology Support SSB

A. The development and use of a catalytic oxidizer for the control of trace contaminants in the AAP Cluster would increase the sophistication of the AAP system as well as providing support for SSB. The catalytic oxidizer oxidizes trace contaminants such as CO, H_2, and other hydrocarbons to larger, less harmful molecules. For future spacecraft with low atmospheric leak rates, this may be the primary means of trace contaminant control.

B. A mass spectrometer which detects CO_2, O_2, N_2 and H_2O has been used successfully in the atmospheric control system of Project Tektite. Its use in the AAP could improve the Cluster atmospheric monitoring system as well as provide for the SSB.

C. A system of vital importance to the success of future spacecraft is the water management system. The AAP could support the SSB in developing techniques and procedures for monitoring water potability and insuring water sterility. In particular, work is now underway at MSC and LRC to develop a water potability analyzer. This might be flown on SWS II if the system has reached a flight hardware stage at that point. In addition, several methods of water sterilization--the use of a silver ion generator and/or the use of thermal sterilization techniques--could be investigated to provide support for SSB.

07. COMMUNICATIONS - R. L. Selden

13. INSTRUMENTATION

Present AAP Support for the SSB

The following technology being developed for AAP relates directly to areas specified in the support plan. References to page numbers of the support plan where the appropriate technology is discussed are included in parenthesis.

1. (Page 7-11) Implement development of high gain antennas. The proposed microwave imaging experiment that is part of the proposed AAP earth resources package includes a 40 inch by 40 inch X-Band array antenna. This antenna, with its 2° beamwidth, is typical of those that might be used in a space station-data relay satellite system. Component technology associated with this experiment to be conducted at 10 GHz is also applicable (page 7-22).

2. (Page 7-17) Autonomous experiment data systems. The experiments in AAP that are assigned to the CSM (e.g. S071/072) are designed as autonomous units including a data system and data storage. These should be at least precusor designs of future experiment packages where in the future the reliability, maintainability and capacity of these subsystems is increased.

3. (Page 7-17) Hard copy printer. SWS-I will be provided with the capability of a hands free operated hard copy teleprinter. This teleprinter may include the capability for both character print out as well as facsimile.

4. (Page 7-11) Electromagnetic Compatibility (EMC) Analysis. This type analysis is being accomplished for SWS-I. This AAP experience should provide refinements in techniques and a better physical understanding of EMC problems.

Potential AAP Support for the SSB

The technology listed below for SWS-II includes that which can reasonably be added to or in place of that used on SWS-I.

1. Provision for an Intelsat IV Communications Satellite relay terminal on SWS-II would provide developed technology in direct support of SSB. Specific related technologies include:

   A. Development of a low-noise (noise figure of 5dB) preamplifier at C-Band (page 7-10).

   B. Determination of techniques for selecting optimum antenna systems for a specified spacecraft configuration and mission support requirements (page 7-11).

   C. Implementation of a high gain antenna (page 7-11). For SWS-II, an antenna with a beamwidth of one degree or less could be implemented.

   D. Development of computer pointing and steering techniques for a high gain antenna (page 7-11). A candidate pointing and steering system for the antenna associated with an Intelsat IV terminal is one using the computer(s) of the ATM to point (acquisition) and/or steer.

2. SWS-II could be provided with a fully integrated data system that includes a computer for formatting, data selection and data compression. (There has been some investigation of this for SWS-I using the computer that is part of an onboard checkout system. This checkout system has been delivered to MSC in a flight version and includes a 4Π/EP computer.) (page 7-5)

3. The system proposed in 2 above could also be implemented with a coded data link. This is particularly attractive if a relay satellite is used. (page 7-5)

4. The use of autonomous experiment data systems could be expanded and further developed on SWS-II. (page 7-17)

5. A common, very stable, timing system could be implemented on SWS-II that would satisfy all module timing requirements. This system could be the one described in the technology plan on (page 13-10).

6. Television system development, particularly cameras, like that proposed in the SSB Technology Plan is already in progress. Much of this development is being accomplished in support of the Earth Resources Technology Satellite (ERTS) program. It is conceivable that an ERTS type payload or a stellar ATM on SWS-II could employ a television camera with a resolution of better than 3000 lines. (page 7-16)

General Comments

The I&C portion of the SSB technology program plan in many places is too general. Descriptors like efficient, high gain, low weight, etc., are used throughout without being related to specific goals. The plan also has some inconsistancies. For example, the RF section requires technology development at S, X and C-Band while the component technology section states an interest in only C and S-Band. I would assume that an iteration of this plan would add technology that has been developed but has not as yet been used in a NASA manned space flight program. An example of this would be programable telemetry systems developed as advanced technology as well as for unmanned space programs.

Two specific areas seem to me to be worthy of comment. The plan calls for development of commercial type telephone systems to be used throughout the SSB and between the SSB and earth. At the same time, it suggests development of voice bandwidth compression techniques (e.g. vocoders). These development efforts would seem to be at odds with one another. Additionally, I do not believe a compressed audio channel would satisfy SSB requirements (such as voice fidelity, compatibility with commercial earth based systems, etc.). I would recommend that this effort be deleted. The second area, worthy of comment, is one of omission. Development of systems and components are proposed for RF systems using S, C and X-Band frequencies and for laser systems. No development is suggested for the frequencies between X-Band (∿10GHz) and light. These are the millimeter wave frequencies generally between 10 and 100GHz (including the Q and V bands). I would recommend effort in this area be added to the plan. (Terrestrial users and the military are showing a lot of interest in this technology.)

08. STABILIZATION AND CONTROL - J. Kranton

Present AAP Support for the SSB

Much of what will be learned in the design of the Attitude Control System for the SWS-I will benefit the SSB. In particular,

1. Use of control moment gyroscopes (2000 ft-lb-sec, 2 year lifetime) for control of spacecraft relative to inertial and local vertical references.

2. Control laws for CMGs and reaction-thrusters for stabilization of a flexible multibody spacecraft whose mass properties change.

3. Redundancy management to the black box level under computer control.

Potential AAP Support for the SSB

1. An artificial-g experiment with an attitude control system that features mass rebalance to orient the principal axis of maximum moment-of-inertia to the spacecraft and points that axis to the sun.

2. A magnetic torque system for momentum management of CMGs. This would obviate the need for reaction thrust or attitude maneuvers to dump bias momentum.

10. GUIDANCE AND NAVIGATION - D. A. DeGraaf

Present AAP Support for the SSB

It appears that continuous on-board navigation is being considered for the SSB. This would require long life automatic sensors with no moving parts to make navigational observations (IR horizon sensor - p. 10-7; sun sensor - p. 10-8; IR yaw steering - p. 10-8; star field mapper - p. 10-8). However, such a complicated system is not justified. In AAP, one of the first things that is done after a vehicle arrives in orbit is that its computer is turned off. Continuous on-board navigation is not required. The orbit does not change; an occasional ground radar measurement is sufficient to monitor the satellite's position and velocity. For those rare occasions when on-board navigation is needed, simple schemes work fine. In addition, Apollo flights have beautifully demonstrated the effectiveness of lunar landmark tracking using the Apollo G&N optics. Experiment D009, Simple Navigation, on Gemini VII and Experiment T002, Manual Navigation Sightings, showed the effectiveness and limitations of hand-held sextants. They are now being considered for repetition in the AAP Program if feasible. Experiment M439, Star/Horizon Automatic Tracking was recently withdrawn from AAP by the MSFEB because required maneuvers cannot be done.

Attitude control is another story. Continuous, long term, high reliability components are essential. The AAP CMG's and the associated redundant digital computer and its software face this requirement squarely. The difficulty of building meaningful redundancy into a computing facility that actually extends its useful life can scarcely be overstated.

Rendezvous radar - an excellent model is available from the Apollo Program.

Docking sensor - a questionable need. We briefly considered the laser radar for use in automatically docking the unmanned LM/ATM, but it was not available in time or budget, so we adopted manual remote control of docking. It is simple, and it works fine. In addition, as long as there is a pilot aboard, automatic docking is not really needed.

Potential AAP Support for the SSB

Any of the new advanced attitude sensors could be carried on SWS-II if a flight test was desired. It is also certain that nothing at all can be added to SWS-I within the remaining time and money. (No current experiments in AAP support the SSB concepts proposed.)

General Comments

Great emphasis is placed on commonality between G&N equipment in the space station and shuttle. This is not reasonable since the two systems will perform accidendly different functions. The shuttle performs many maneuvers. However, the only maneuvers required of a SSB would seem to be for combating orbit decay, and that surely can be done manually.

18. CHECKOUT - C. H. Eley, III

Present AAP Support for the SSB

The support AAP is currently planning for the SSB in the area of checkout is primarily on-board data management. There is nothing new with respect to ground checkout.

The on-board data management system in AAP should greatly contribute to development of the Information Management System (IMS) for the SSB. Specific hardware that the Orbital Workshop (OWS) will carry consists of:

1. Data buffer unit and mass memory

2. Flight computer

3. Control and display unit

The basic operation of the AAP equipment will be to take selected data off of the telemetry bit-stream for processing and display to the flight crew. This will actually be in the category of an experiment to assess the design and utility of such a system in space.

Potential AAP Support for the SSB

At present, there appears to be little in the area of ground checkout with respect to technology or engineering precursor developments that could be added to the OWS to support the SSB.

General Comments

The checkout portion of the Space Station Technology Program Plan needs to be rewritten and a clearer distinction made between ground checkout equipment, on-board checkout equipment and the interface between the two. The checkout concept presented in the plan appears far more applicable to the Space Shuttle than the SSB.

19. ASTRONAUT EQUIPMENT - W. W. Hough
L. D. Sortland

We have reviewed the subject portions of the Space Station Technology Plan. Current technological support provided by AAP is listed. Possible additional support of the Plan that might be provided by AAP is also listed, including comments on the capability of SWS-I to provide such support. If it is judged infeasible for SWS-I to be modified, because of cost or schedule impact, the added AAP technological support must wait for SWS-II.

Present AAP Support for the SSB

Through both experiments and planned operational modes, AAP will be supporting the development of astronaut equipment. Experiment M508 is designed to evaluate the work ability of a man wearing advanced space suits, and thus provide an evaluation of the suits themselves. Two experiments deal specifically with the evaluation of maneuvering aids for astronauts. These are the M509 Maneuvering Unit and the T020 Jet Shoes.

Extravehicular activity is used in AAP as the only operational mode for ATM film retrieval. This should provide more information on the acceptability, or possibly the desirability, of EVA as a normal operating procedure.

AAP currently plans to evaluate new intervehicular garment designs, but will not go so far as to provide laundering capability.

Potential AAP Support for the SSB

AAP uses an open-loop, vehicle-dependent, life support system for operational EVA, and is not, as a program, developing advanced, closed-loop, portable systems. Such advanced systems are being developed, however, and AAP can serve as a test bed for them. In the case of portable equipment such as this, there would be no cost or schedule impact to the Program, and if the systems are ready, they could be flown on SWS-I. In SWS-II, advanced portable systems, high mobility suits, and the experience of operational EVA on SWS-I might be combined to give much greater operational EVA capability.

30. BIOMEDICAL/BEHAVIOR - R. E. McGaughy

Present AAP Support for the SSB

1. SWS experiments which support the SSB: All of the approved AAP medical experiments are designed to support the SSB because they will test the capabilities of man in space and measure his adaptation to weightlessness.

2. SWS technology and engineering precursor developments which support SSB:

   A. The IMBLMS medical measurement system will be ready for SWS II and will be more extensively developed for SSB.

   B. Improved microbiological and toxicological monitoring of the crew quarters will lead to a complete system in SSB flights.

Potential AAP Support for the SSB

1. Experiments which could be added to SWS to support SSB:

   A. A systematic method of crew behavior observations similar to the methods used in the Tektite project. This should be aimed at evaluating personal adjustment and social interaction among crew members, and requires several on-board TV cameras and a special private communications link one way from spacecraft to ground.

   B. On-line measurements of the electroencephalogram (brain-wave) of crew members, at least during sleep but also during waking hours.

2. Technology developments which could be added to SWS to support SSB:

   A. The IMBLMS capability could be expanded to emphasize comprehensive data collection for each crew member and automatic correlation of on-line data with his past medical history. The goal would be to make an on-line diagnosis of medical problems and to predict crew readiness to undertake the next mission phase.

   B. Medical studies aimed at assessing the value of artificial gravity in counteracting any adverse effects of zero gravity which might show up in the 56-day weightless SWS I mission.

33. INFORMATION MANAGEMENT SYSTEM - D. O. Baechler

Potential AAP Support for the SSB

1. The SSB program has a requirement for interfacing data streams from several sources (page 33-14) and for reducing redundancy to effect data compression (page 33-19). This requirement is particularly important because the overall size and complexity of the space station is such that raw data from the many different sources cannot feasibly be handled any other way.

   It has been suggested that three real time AAP data streams be merged and compressed using a redundancy reduction algorithm. A Bellcomm Memorandum for File, "Onboard Computing Capability Required to Compress AAP Telemetry Data," January 7, 1970, concluded that based primarily on a GSFC study it would be feasible to merge only two of the streams if an IBM 4 PI/EP computer was used. Further study of this problem with the goal of demonstrating compression and interfacing of more than one data stream would support the SSB requirements stated above.

2. The concept of a data bus affects the entire space station design and therefore its feasibility deserves early study. Also, software and hardware must be developed to provide a high degree of interaction between the IMS and the crew members who do not have extensive programmer training. The MSC onboard checkout system described on page 33-9 is capable of demonstrating these techniques. It is being considered as an AAP experiment to demonstrate the use of multipurpose displays and a high-level interactive language that can be used by persons with no training in the language. This feasibility demonstration should be encouraged, and an attempt should be made to partially integrate the system into AAP to study the feasibility of the data bus concept.

General Comments

In general, the Information Management System portion of the Space Station Technology Program Plan is realistic and is in agreement with studies by Bellcomm's NASA Computer Technology Group. The following are suggestions for strengthening the plan.

The schedule for software development seems overly optimistic; software may be the pacing item in the IMS development and is worthy of separate study of the type outlined for hardware in Section A, IMS Analysis.

A very important statement on page 33-10 is that ground rules must be imposed on subsystem designers during the initial vehicle design phases to standardize subsystem interfaces and checkout philosophies. This is equally important to support the data bus concept. It could be added that subsystem designers must provide diagnostic procedures that can be used in developing the maintenance support system.

The objectives outlined in the technical matrix are generally realistic although there are some fine points that could be discussed - for instance, 10^8 bit computer active memories in 1972 will probably consume 20 watts rather than 10 watts. Two significant points are that (1) cycle times for spacecraft LSI computers in 1972 and 1977 will probably be significantly less than the 10 μsec and 2 μsec listed and (2) plated wire memories are good candidates for mass memory in 1972, yet they are not mentioned anywhere in the program plan while an overly optimistic view of optic memory is taken.

36. MECHANICAL SYSTEMS - R. J. Ravera

Present Support AAP is Providing to the SSB

1. Docking and orbital assembly (pages 36-2): There is a wealth of relevant Apollo and AAP experience concerning analytical methods and test techniques in the area of docking. This experience exists in each of the five tasks listed on page 36-3.

2. Windows: AAP experiment S-190, Multispectral Photographic Facility interfaces with a 16-1/2" by 19" window which will be required to retain high optical quality for the 8 month AAP mission. There are window specifications made for parallelism, optical quality, seeds and bubbles, resistance to damage, surface quality, transmittance and coatings.

3. Airlocks and hatches: There will be much AAP design and performance experience on airlocks and hatches. AAP currently has four airlocks: an EVA airlock in the AM, an airlock for refuse dump in the SWS, and two scientific airlocks on opposite sides of the SWS. There are in addition several hatches: between SWS and AM, SWS to waste tank, CM to MDA, EVA hatch in AM airlock, and hatches from AM airlock to forward and aft compartments of the AM.

4. Rotating interfaces: The Apollo Telescope Mount (ATM) can be viewed as a well instrumented test-bed for rotating interface hardware in a space environment. It includes gimbals, roll rings, bearings, movable optics, mechanical drives and associated lubricants. On some components, comparative wear tests are now being run between dry and wet lubricants.

5. Assembly of hardware in orbit: AAP experiments M508 (EVA Hardware Evaluation) and M512(Materials Processing in Space) might be applicable.

6. Other devices: AAP experience on proposed materials and lubricants, in the areas of control and development, can be useful. Note, for example, the document "ATM Materials Control for Contamination Due to Outgassing," 50M02442, MSFC. This document references materials for approval or disapproval in a space environment. New materials such as Dupont's VESPEL which has self lubricating properties, and new lubricants such as Ball Brothers' VAC KOTE will be evaluated on AAP. The design and performance in a space environment of control moment gyros, flex pivots and other devices and processes should be relevant to space station technological requirements.

37. CRYOGENICS - R. J. Ravera

Present AAP Support for the SSB

1. Applicable AAP support is related primarily to tasks 1) and 2) on page 37-3. NASA funded the Bendix Corp., Instrument and Life Support Division, to develop the Cryogenic Gas Storage System (CGSS) for AAP (Contract NAS 9-7689). The contract was cancelled a few months after the critical design review with the advent of the dry workshop. Nevertheless, AAP has funded research and development of a CGSS with 41.5" OD tanks for 60-90 day mission capability; this effort probably represents the state-of-the-art, as is acknowledged in Table 37-II, under "1969 status." Bendix feels the basic CGSS design can be adapted for 360 day missions, a 1972 objective in Table 37-II.

38. MATERIALS - J. E. Waldo

Present AAP Support for the SSB

1. Currently planned AAP experiments will give needed data on launch and space degradation of coatings, which can be used for SSB and other missions.

   A. M415 - Groupings of various thermal control coatings are mounted on the instrument unit of the launch vehicle. They are sequentially exposed during launch, and their temperatures are measured in orbit.

   B. D024 - Thermal control coatings are exposed in the earth orbit environment and then returned. (This experiment has been accepted.)

2. Current AAP technology and engineering precursor developments which support SSB:

   A. The institution of a two-gas environment has been cited (page 38-1) as creating a need for more materials research. Since AAP laready has a two-gas environment, the need for such research should be greatly diminished.

   B. AAP now employs fusible materials for heat storage (wax capacitor in the AM).

   C. D021 - "Expandable airlock" which tests the feasibility of expandable structures.

Potential AAP Support for the SSB

1. Additional AAP experiments that could support SSB:

   A. The possibility of using peelable thermal control coatings to extend useful life or adjust thermal characteristics could be tested. A particular problem here is developing easy fastening or bonding techniques that resist space vacuum.

   B. Some phototropic coatings (ε and α vary with temperature) have been investigated. Their behavior in space could be tested on AAP.

2. Additional technology and engineering precursor developments that could support SSB:

   Inflatable structures, as part of a sun shield, could be incorporated in the AAP missions without undue scheduling difficulties.

39. AEROTHERMODYNAMICS - D. A. De Graaf

Present AAP Support for the SSB

1. If today's atmospheric models are inadequate for space station studies, it is too bad. The Jacchia model used in AAP almost perfectly predicts density, provided solar activity is input. Unfortunately, this key parameter cannot be predicted, except grossly. Thus, drag dependent factors, such as orbit-keeping propulsion and attitude control propulsion, must be sized to contend with a considerable range of uncertainty. (On page 39-3 it says the Jacchia Atmosphere is limited to suborbital altitudes. In fact, it is good only at orbital altitudes, up to 550 Km.)

   Precision tracking of the AAP workshop will add more data to deduce high altitude density, but probably not as good data as from several hundred prior satellites. Waste venting and random attitude maneuvers can be expected to perturb the orbits - both for AAP and the space station.

General Comments

Plume impingement seems to be a black art today. But it is also not much of a problem. The current AAP thinking is that we have no structural problems but that contamination of the solar panels and thermal control surfaces are a bit of a mystery. Conceivably, AAP experience will prove useful. Photographs of the SWS before and after exposure might also be useful, but there are no plans to get some. Experiment D024, Thermal Control Coatings, is designed to measure effects of space exposure.

40. MAN-SYSTEM-VEHICLE INTEGRATION - W. W. Hough, L. D. Sortland

Present AAP Technology Support for the SSB

AAP is the first manned program to really emphasize the habitability aspects of space flight. Most of the sub-elements of habitability detailed in the Plan (pages 40-2/40-4) have been included in the design of the SWS, and the AAP design will be evaluated by the three AAP crews. These include zero-g crew quarters and working areas. An experiment is devoted to evaluation of a zero-g work bench. Crewman mobility and restraint in zero-g and in a large volume will be evaluated. Many new concepts in food and food management will be tried in AAP, including freezers and ovens. A zero-g galley, eating area, and ward-room will be provided.

AAP's waste management system is designed around specific medical experiments which require sampling and treating of human waste. Although some features will be the same in SSB, evaluation of an operational biowaste system is impossible in AAP in view of the medical requirements. AAP will permit evaluation of housekeeping problems encountered in large living volumes.

The safety-assurance equipment section of the plan discusses many safety devices that would be inapplicable and useless in AAP. The author of the section apparently visualizes the space station as a big red-cross in the sky. AAP does include an emergency warning system for fire and depressurization, but little else in this author's wish-list.

AAP is supporting the development of human factors technology through the habitability support system and through flight demonstration of selected equipment.

Potential AAP Technology Support for the SSB

An artificial gravity experiment has been proposed for the second SWS. If implemented, the rotating environment and an architecture for artificial-g can be evaluated in SWS-II. So can the effects on crewman mobility, internal cargo handling, etc.

If medical experiment requirements are satisfied during SWS-I, then a more advanced waste-management system might be included and evaluated in SWS-II. A whole-body shower and an intravehicular garment laundry are examples of systems which could be integrated with SWS-II as either technology experiments or operational systems.

BELLCOMM, INC.

Subject: Review of Space Station Technology Program Plan - Case 620

From: G. M. Anderson, et al

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